

CLAIMS

What is claimed is:

1. A method for providing a glass preform for use as a source for drawing an optical fiber, the method comprising the steps of:

5 collecting a plurality of first glass rods into a substantially contiguous bundle, wherein each of said first glass rods comprises a chemical composition and has a substantially uniform shape; and

10 heating said contiguous bundle to a glass fusion temperature and causing said contiguous bundle to fuse to form a solid glass preform such that said chemical composition of each of said first glass rods is maintained in a location proximate or about coincident with a position of each said glass rods within said contiguous bundle.

15 2. The method of claim 1, wherein said step of collecting further includes a step of inserting said contiguous bundle into a glass tube, wherein said glass tube has an inside diameter chosen to contain said contiguous bundle, forming thereby a preform assembly.

3. The method of claim 2, wherein said step of heating further comprises heating said contiguous bundle such that fusion begins at one end progresses along a length of said preform assembly.

20 4. The method of claim 1, wherein said chemical composition of each of said first glass rods is chosen to provide one of two or more different refractive indices, and wherein said step of collecting further includes combining said first glass rods so as to provide a predetermined, average refractive index to said contiguous bundle, said average refractive index falling within a range spanned
25 by said two or more refractive indices.

5. The method of claim 4, wherein said first glass rods are combined so as to be randomly distributed throughout said contiguous bundle.

6. The method of claim 4, wherein said first glass rods are combined so as to be evenly and non-randomly placed throughout said contiguous bundle.

7. The method of claim 1, wherein said plurality of first glass rods further comprises a first quantity of glass rods having a first refractive index slightly greater than a target refractive index, and a second quantity of glass rods having a second refractive index slightly less than said target refractive index such that a numerical average of said refractive indices of said first and second quantities of first glass rods is substantially equal to said target refractive index.

8. The method of claim 1, further including the step of removing and replacing one or more groups of contiguous first glass rods with an equivalent number of groups comprising second glass rods, said second glass rods comprising a chemical composition and having a substantially uniform shape, said second glass rods comprising a physical or chemical property having a different value than a value of said same physical or chemical property of said first glass rods.

9. The method of claim 8, wherein the step of removing and replacing further includes the step of partially displacing said one or more first groups from said preform assembly.

10. The method of claim 8, wherein said chemical composition of said first or said second glass rods comprises compounds of one or more of the elements selected from the list of elements consisting of boron, aluminum, silicon, germanium, phosphorous, lead, the halides, and the alkali and alkaline-earth elements, and combination of these compounds thereof.

11. The method of claim 8, wherein the step of displacing, and the step of removing and replacing, are performed by inserting a stepped template into one end of said glass tube and against one end of each of said first glass rods, said stepped template having one or more steps or plugs, said steps or plugs acting to partially displace said one or more groups of first glass rods.

12. The method of claim 11, wherein said plugs have a desired shape and size and are located in a desired position in a cross section of said preform assembly.

13. The method of claim 12, wherein said one or more plugs of said stepped template are removable, and wherein said step of removing and replacing further
5 includes the step of removing one or more of said plugs such that longitudinal spaces equivalent to each said one or more plug shapes remain within said stepped template and within said perform bundle adjacent to said stepped template, said spaces in said stepped template and said perform bundle acting as a guide to allow entry, and for inserting and fully displacing each of said one
10 or more groups of said first glass rods with said one or more equivalent groups of said second glass rods.

14. The method of claim 11, wherein said one or more groups consists of a single, contiguous core bundle of second glass rods inserted about a central longitudinal axis of said perform assembly, and wherein said second glass rod
15 chemical composition comprises one or more rare-earth dopant elements.

15. The method of claim 14, wherein said contiguous core bundle is formed by inserting and replacing successively smaller bundles of second glass rods along said longitudinal axis, wherein each successive bundle of second glass rods comprising a rare-earth composition which is different than each preceding
20 bundle, thereby providing a perform core region having a graded or structured rare-earth-dopant concentration.

16. The method of claim 14, wherein said contiguous core bundle is formed by inserting and replacing successively smaller bundles of glass rods along said longitudinal axis, wherein each successive bundle of glass rods comprises a
25 fractional combination of second glass rods distributed in a fixed quantity of first glass rods, and wherein each smaller bundle consists of a larger fraction of second glass rods than each preceding bundle thereby providing a perform core region having a graded or structured rare-earth-dopant concentration.

17. The method of claim 9, wherein said one or more groups consists of a single elliptical bundle of first glass rods, and wherein said second glass rods further comprise a glass having a coefficient of thermal expansion different than said first glass rods.

5 18. The method of claim 9, wherein said one or more groups comprise two equal and opposing radial sections of first glass rods, and wherein said second glass rods further comprise a glass having a coefficient of thermal expansion different than said first glass rods.

10 19. The method of claim 18, wherein said radial sections are sectors of an annulus.

20. The method of claim 18, wherein said radial sections are circular sections.

15 21. The method of claim 2, wherein said glass tube is evacuated and sealed at first and second ends such that said contiguous bundle is enclosed under an internal pressure below 1 atmosphere, and wherein further said contiguous bundle is restrained at each end within said sealed glass tube by a porous packing plug.

22. The method of claim 21, wherein said porous packing plug comprises a high purity glass wool.

20 23. The method of claim 22, wherein said step of heating further comprises moving said a-first end of said preform assembly longitudinally into a heated zone of a furnace means such that fusion begins at said first end and progresses toward said second end as said preform assembly is moved through said heated zone.

24. The method of claim 22, wherein the furnace means is a tube furnace.

25 25. The method of claim 23, further including rotating said preform assembly.

26. The method of claim 25, wherein said preform assembly is heated to a temperature of about 1500°C.

27. The method of claim 23, further including maintaining an external pressure within said furnace greater than one atmosphere.

28. The method of claim 1, wherein each of said plurality of first or second glass rods has an outer diameter of not less than 0.1 mm and not more than 5 mm and wherein said bundle contains between about 30 to about 30,000 glass rods.

29. The method of claim 1, wherein said preform bundle has a diameter of between about 0.5 cm and about 10 cm.

30. The method of claim 14, wherein said rare-earth dopants are selected from the list consisting of praseodymium, neodymium, samarium, holmium, erbium, thulium, and ytterbium.

31. The method of claim 14, wherein said rare-earth dopants are present in concentrations ranging from about 0.01% by weight to about 5% by weight.

32. The method of claim 30, wherein said second glass rods further comprise a co-dopant species for increasing the solubility of said one or more rare-earth dopant elements and for adjusting a refractive index, said co-dopant selected from the list of elements consisting of boron, aluminum, silicon, phosphorous, germanium, fluorine, zinc, zirconium, titanium, sulfur, selenium, and tellurium.

33. The method of claim 1, wherein each of said first glass rods is made by the method, comprising the steps of:

providing a plurality of glass rods, wherein each of said glass rods comprises a chemical composition providing one of two or more different refractive indices;

collecting said plurality of glass rods so as to provide a substantially contiguous bundle of glass rods having a predetermined, average refractive index falling within a range spanned by said two or more refractive indices;

inserting said contiguous bundle into a glass tube, wherein said glass tube has an inside diameter chosen to contain said contiguous bundle, forming thereby a glass preform assembly;

heating said glass preform assembly to a glass fusion temperature thereby causing said preform assembly to fuse to form a solid glass preform such that said chemical composition of each of said glass rods is maintained in a location proximate or about coincident with a position of each said glass rods within said preform assembly; and

drawing a plurality of glass rods from said solid glass preform, each of said glass rods comprising said average refractive index.

34. The method of claim 8, wherein said second glass rods comprise a means for eliminating or substantially reducing propagation of amplified spontaneous emission.

35. The method of claim 34, wherein said means for eliminating or substantially reducing propagation of amplified spontaneous emission comprises one or more dopant compounds.

36. The method of claim 34, wherein said means for eliminating or substantially reducing propagation of amplified spontaneous emission is substantially restricted to an outer portion of an inner cladding.

37. The method of claim 35, wherein said means for eliminating or substantially reducing propagation of amplified spontaneous emission comprises one or more transition metal dopant compounds comprising elements selected from the group of elements consisting of new IUPAC Groups 4 – 7 of the Periodic Table of Elements.

38. The method of claim 37, wherein said means for eliminating or substantially reducing propagation of amplified spontaneous emission comprises a metal dopant containing one or more elements selected from the list consisting of terbium, titanium, and zirconium.

39. A method for providing a glass preform for use as a source for drawing an optical fiber, the method comprising the step of:

providing first and second quantities of glass rods, wherein each of said glass rods has a substantially uniform shape, said first quantity comprising one or more rare-earth dopant elements, said second quantity comprising first and second refractive indices, wherein said first refractive index is greater than a target refractive index, and said second refractive index is less than said target refractive index;

collecting said plurality of first quantity of glass rods into a substantially contiguous bundle of rods, forming thereby a first bundle, said first bundle for forming a preform core region having a substantially uniform radial and longitudinal chemical composition;

uniformly surrounding said first bundle with said second quantity of glass rods forming thereby a contiguous and substantially concentric cylindrical annulus about said first bundle, wherein said first and second refractive indices are distributed throughout said cylindrical annulus so as to provide an average refractive index within said cylindrical annulus substantially equal to said target refractive index, said second quantity of glass rods forming a cylindrical preform cladding region surrounding said preform core region to provide a glass preform bundle;

inserting said glass preform bundle into a glass tube wherein said glass tube has an inside diameter chosen to contain said glass preform bundle; and

heating said glass tube and said glass preform bundle to a glass fusion temperature thereby causing said glass tube and said glass preform bundle to fuse in place to form a solid glass preform such that said preform core region radial and longitudinal chemical composition and said cladding region average refractive index are maintained.

40. The method of claim 39, wherein said glass tube is evacuated and sealed at first and second ends such that said preform bundle is enclosed under an internal pressure below 1 atmosphere, and wherein further said preform bundle is restrained at each end within said sealed glass tube by a porous packing plug.

5 41. The method of claim 39, wherein said porous packing plug comprises a high purity glass wool.

42. The method of claim 39, wherein said step of heating further comprises moving of said glass tube and said glass preform assembly into a heated zone of a furnace means longitudinally such that begins at one end and slowly
10 progresses along a length of said tube and said glass rods as said preform assembly is moved through said heated zone.

43. The method of claim 42, wherein the furnace means is a tube furnace.

44. The method of claim 42, further including rotating said preform assembly.

45. The method of claim 44, wherein said preform assembly is heated to a
15 temperature of about 1500°C.

46. The method of claim 39, wherein each of said first and second quantity of glass rods has an outer diameter of not less than 0.1 mm and not more than 5 mm and wherein said glass preform bundle contains between about 30 to about 30,000 glass rods.

20 47. The method of claim 39, wherein said glass preform bundle has a diameter of between about 0.5cm and about 10 cm.

48. The method of claim 39, wherein said rare-earth dopant elements are selected from the list consisting of praseodymium, neodymium, samarium, holmium, erbium, thulium, ytterbium.

25 49. The method of claim 48, wherein said second glass rods further comprise a co-dopant species for increasing the solubility of said one or more rare-earth dopant elements and for adjusting a refractive index, said co-dopant selected

from the list of elements consisting of boron, aluminum, silicon, phosphorous, germanium, fluorine, zinc, zirconium, titanium, sulfur, selenium, and tellurium.

50. The method of claim 39, wherein said first glass rods comprising one or more transition metal dopants selected from the group of elements consisting of new IUPAC Groups 4 – 7 of the Periodic Table of Elements.

51. The method of claim 50, wherein said first quantity of glass rods further comprise a metal dopant for substantially reducing or eliminating amplified spontaneous emission, said metal dopant selected from the list consisting of terbium, titanium, and zirconium.

52. A glass preform for providing a drawn optical fiber, comprising:

a plurality of first and second glass rods, each of said rods having a chemical composition comprising silica, said first rods further comprising a rare-earth dopant, said first rods bundled together to form a substantially contiguous core bundle, said wherein said chemical composition of each of said second glass rods chosen to provide one of two or more different refractive indices, said second glass rods uniformly surrounding said core bundle in the form of a substantially cylindrical annulus, such that said cylindrical annulus has an refractive index falling within a range spanned by said two or more refractive indices substantially equal to a predetermined average refractive index, said cylindrical annulus forming a cylindrical preform cladding region surrounding said preform core region to provide a composite preform bundle; and

a glass tube surrounding and containing said composite preform bundle, said glass tube and said composite preform bundle fused at a glass fusion temperature to form a solid glass preform such that said chemical compositions of each of said glass rods is maintained in a location proximate or about coincident with a position of each said glass rods within said glass preform bundle.

53. A method for providing a plurality of high purity glass rods, comprising the steps of:

providing a source of one or more reactant materials;

heating said reactant materials in the presence of oxygen contained in a
5 flowing gas stream thereby providing one or more oxides of said one or more
reactant materials, said oxides forming as a finely dispersed powder;

collecting said oxide powder in a silica ampule;

melting said collected powder and said silica ampule to form a substantially
uniform glass boule; and

10 drawing said boule into one or more glass rods.

54. The method of claim 53, wherein said step of providing includes providing a
plurality of reactant materials, and wherein said step of heating includes forming
a plurality of oxide powders.

55. The method of claim 53, wherein said step of heating said reactant materials
15 further comprises heating with a tube furnace or with a ring burner.

56. The method of claim 53, wherein said step of collecting further includes
collecting a predetermined quantity of said oxide powders by measuring an
incremental weight gain of said silica ampule as said powders are collected.

57. The method of claim 53, wherein said reactant materials comprise one or a
20 combination of halide compounds and chelated complexes.

58. The method of claim 57, wherein said halide compounds and chelated
complexes comprise materials selected from the list consisting of boron,
aluminum, silicon, phosphorous, sulfur, germanium, selenium, tellurium, iron,
zinc, zirconium, titanium, or any of the lanthanide rare earth elements.

forming a plurality of finely dispersed oxide powders by heating one or more reactant materials in the presents of oxygen;

heating said collected powders and said silica ampule in order to melt said powders and said silica ampule to form a ductile glass boule; and

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